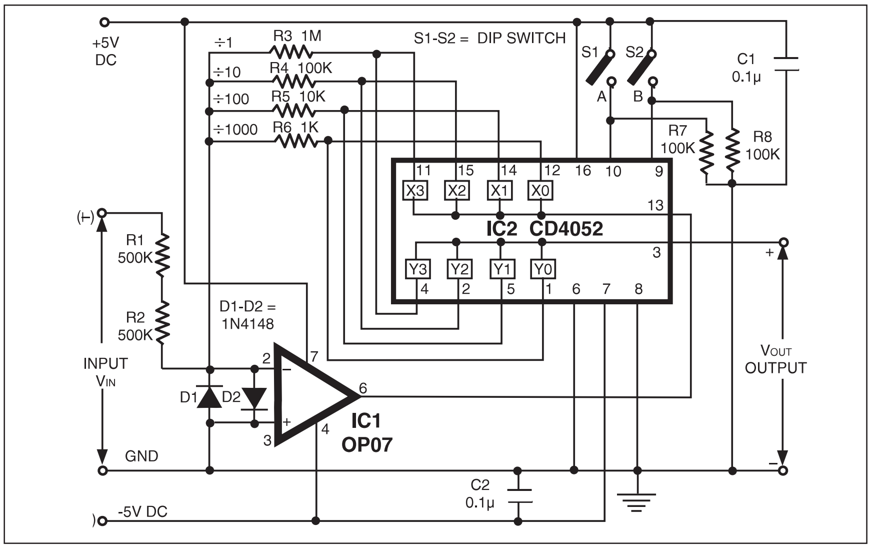
PRECISION ATTENUATOR WITH DIGITAL CONTROL

When instruments are designed, an analogue front-end is essential. Further, as most equipment have digital or microcontroller interface, the analogue circuit needs to have digital control/access.

The circuit of a programmable attenuator with digital control is described here, where digital control can be a remote dip switch, or CMOS logic outputs of a decade counter (having binary equivalent weight of 1, 2, 4, and 8, respectively), or I/O port of a microcontroller like 80C31.

The heart of this circuit is the popular OP07 op-amp with ultra-low offset in the inverting configuration. A dual, 4-channel CMOS analogue multiplexer switch CD4052 enables the change in gain. An innovative feature of the circuit is that the 'on' resistance (around 100 ohms) of CD4052 switch is bypassed so that no error is introduced by its use.

Resistors R1 to R6 used in the circuit should be of 0.1 per cent tolerance, 50 ppm (parts per million) if you use 3½-digit DPM, i.e. ±1999 counts (approx. 11 bits). But for 4½-digit DPM (approx. 14 bits), you may need to have trimpots (e.g. replace 1k-ohm resistor R6 by a fixed 900-ohm resistor in series with a 200-ohm trimpot) to replace R3, R4, R5, and R6 gain selection resistors for proper calibration to required accuracy. However, for testing or trials, use 1 per cent 100ppm MFR resistors. The expected errors will be around 1 per cent.



To keep parts count (hence cost) to a minimum, the common or ground is used as the positive input terminal and one end of resistor R1 as the negative. This is so because the op-amp inverts the polarity as it is used in inverting configuration. This does not matter as the equipment will be isolated by the power supply transformer and all polarities are relative. In case you want the common to be the negative, you will have to add some stages (IC4 and IC5 circuitry shown in precision amplifier circuit described later).

The OP07 pinout is based on standard single op-amp 741. Any other op-amp like CA3140, TLO71, or LF351 can be used but with offset errors in excess of 1 per cent, which is not tolerable in precision instrumentation.

The OP07 has equivalent ICs like µA741 and LM607 having ultra-low offset voltage (<100µV), low input bias current (<10nA), and high input impedance (>100M), which are the key requirements for a good instrumentation op-amp for use with DC inputs.

The following design considerations should be kept in mind:

(a) Input: 500V max

Since ¼W resistors can withstand up to 250V, resistors R1 and R2 in series are used for 1 meg-ohm with 500V (max) input limit. These resistors additionally limit the input current as well. Diodes D1 and D2 clamp the voltage across input of op-amp to ±0.5V, thereby protecting the op-amp.

Truth Table (Control input VS attenuation)

X,Y (ON-switch Pair)	(2) B	(1) A	Gain (Attenuation)
X0,Y0	0	0	1/1000
X1,Y1	0	1	1/100
X2,Y2	1	0	1/10
X3,Y3	1	1	1

(b) Output

The output can be connected to a 7107/7135-based DPM or any other analogue-to-digital converter or op-amp stage. Use a buffer at the output if the output has to be loaded by a load less than 1 meg-ohm.

Use an inverting buffer if input leads have to have polarity where ground is the inverting terminal. (For details, see next circuit.)

(c) CD4052 CMOS switch

The on-resistance (100-ohm approx.) comes in series with the op-amp output source resistance, which produces no error at output.

Caution. The circuit does not isolate, it only attenuates. When high voltage is present at its input, do not touch any part of the circuit.

(d) Digital control options

(i) A and B can be controlled by I/O port of a microcontroller like 80C31 so that the controller can control gain.

(ii) A and B can be given to counters like 4029/4518 to scroll gain digitally.

(iii) A and B can be connected to DIP switch.

(iv) A and B can be connected to a thumbwheel switch.

Notes. 1. Digital input logic 0 is 0V and logic 1 is 5V.

2. All resistors are metal film resistors (MFR) with 1% tolerance, unless specified otherwise.

3. C2 and C3 are ceramic disk capacitors of 0.1µF = 100nF value.